PCT/GB03/005210

The Patent Office

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

# PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

REC'D 08 MAR 2004

WIPO PCT

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.



Signed M Caskie

Dated 23 February 2004

Patents Form 1/77

Patents Act 1977
(Rule 16)

THE PATENT OFFICE
A
23 DEC 2002
RECEIVED BY FAX

The Patent Office

23DEC02 E772779-1 D02861
P01/7700 0.00-0229763.8

1/77

# Request for grant of a patent

*(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)*

23 DEC 2002

The Patent Office
Cardiff Road
Newport
South Wales
NP10 8QQ

| | | |
|---|---|---|
| 1. | Your reference | 583GB |
| 2. | Patent application number *(The Patent Office will fill in this part)* | 0229763.8 |
| 3. | Full name, address and postcode of the or of each applicant *(underline all surnames)* | Renishaw plc<br>New Mills<br>Wotton-under-Edge<br>Gloucestershire, GL12 8JR |
| | Patents ADP number *(if you know it)* | 2691002 |
| | If the applicant is a corporate body, give the country/state of its incorporation | United Kingdom |
| 4. | Title of the invention | Signal Transmission System For A Trigger Probe |
| 5. | Name of your agent *(if you have one)* | E C Leland et al |
| | "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* | Renishaw plc, Patent Department<br>New Mills<br>Wotton-under-Edge<br>Gloucestershire<br>GL12 8JR |
| | Patents ADP number *(if you know it)* | 8187429001 |

| | | Country | Priority application number *(if you know it)* | Date of filing *(day / month / year)* |
|---|---|---|---|---|
| 6. | If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number | - | - | - |

| | | Number of earlier application | Date of filing *(day / month / year)* |
|---|---|---|---|
| 7. | If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application | - | - |

| | | |
|---|---|---|
| 8. | Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*<br>*a) any applicant named in part 3 is not an inventor, or*<br>*b) there is an inventor who is not named as an applicant, or*<br>*c) any named applicant is a corporate body.*<br>*See note (d))* | Yes |

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

| | |
|---|---|
| Continuation sheets of this form | |
| Description | 19 / CF |
| Claim(s) | 0 |
| Abstract | 0 |
| Drawing(s) | 6 only |

10. If you are also filing any of the following, state how many against each item.

| | |
|---|---|
| Priority documents | 0 |
| Translations of priority documents | 0 |
| Statement of inventorship and right to grant of a patent *(Patents Form 7/77)* | 0 |
| Request for preliminary examination and search *(Patents Form 9/77)* | 0 |
| Request for substantive examination *(Patents Form 10/77)* | 0 |
| Any other documents *(please specify)* | 0 |

11. I/We request the grant of a patent on the basis of this application.

Signature E Iles Date 23.12.02

AGENT FOR THE APPLICANT

12. Name and daytime telephone number of person to contact in the United Kingdom — A ILES 01453 524524

**Warning**

*After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.*

**Notes**

*a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.*

*b) Write your answers in capital letters using black ink or you may type them.*

*c) If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

*d) If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

*e) Once you have filled in the form you must remember to sign and date it.*

*f) For details of the fee and ways to pay please contact the Patent Office.*



0056259 23-Dec-02 01:34

# SIGNAL TRANSMISSION SYSTEM FOR A TRIGGER PROBE

This invention relates to probes for use on machines which determine a position of a workpiece, such as a coordinate measuring machine or machine tool. More particularly, it relates to signal transmission systems for such probes.

A trigger probe for such purposes is described in US Patent No. 4,153,998. In use, the probe is moved by the machine relative to a workpiece. The probe has a deflectable stylus and delivers a trigger signal when the stylus contacts the workpiece. The trigger signal is indicated by the probe switching from one state to another. The trigger signal is used by the machine controller to freeze the outputs of scales or other measuring means which indicate the position of the probe. The position of the point of contact on the workpiece surface can thus be determined.

Especially on machine tools, it can be difficult to wire the probe directly to the machine controller, and so various wireless signal transmission systems have been developed in the prior art. These include inductive systems (where the signal is transmitted by electromagnetic induction between two coils), optical systems (where an optical emitter such as an infra-red diode is provided on the probe and produces an optical signal which is received by an appropriate receiver) and radio systems (having a radio transmitter in the probe and a radio receiver fixed at a convenient location on the machine). An example of a radio system is shown in US Patent No. 4,119,871. An important requirement of such probes is repeatability, i.e. that

the same result should be achieved every time a given measurement is repeated. The mechanical position of the stylus in the probes described in US Patent No. 4,153,998 is extremely repeatable in space, an instant of production of the trigger signal always has a definite, repeatable relationship with the instant of contact between the stylus and the workpiece. This means that accurate results can be obtained from the probe by a simple calibration procedure.

However, the accuracy would be destroyed if the signal transmission system were not repeatable, that is, if there were an unknown, variable delay in the signal transmission. If this occurs then the probe would travel an unknown variable distance after the instant of generation of the trigger signal before the machine control is able to freeze the outputs of the measuring means. There is then an error between the position of contact and the position indicated by the frozen outputs and this error is an unknown variable quantity which cannot be removed by calibration. Thus, in order to maintain overall accuracy of the probe system there is the problem of ensuring that any transmissions delays introduced by the signal transmission system are repeatable i.e. the same delay should be introduced every time the probe is triggered. The probe calibration procedure mentioned above will then also remove this repeatable delay caused by the transmission system.

US Patent No. 5,279,042 discloses an analogue radio signal transmission system for a probe in which the probe is provided with a transmitter for producing a carrier signal onto which a probe signal may be

modulated. A receiver receives the probe data and produces a probe output signal derived from the transmitter data. A clock on the transmitter provides a time standard for the whole system, the receiver uses an oscillator with a phase comparator at its input to ensure that the oscillator is permanently synchronised with a clock in the transmitter. When a probe signal occurs, the time elapsed between the start of a counter cycle and the change of state of the probe is latched in a shift register and transmitted serially.

This method has the disadvantage that as the transmitter transmits a continuous signal which is required to synchronise the transmitter and receiver the system uses a significant proportion of the probe battery power and thus reduces the battery life.

Furthermore, in a fixed frequency system, the number of available communication channels is equal to the limited number of frequency channels. There is therefore the problem of receivers from other systems which use this frequency channel intercepting the transmission sent from the probe. In addition, the presence of radio traffic may affect the transmissions.

The present invention provides a transmission system for a touch trigger probe for a position determination machine comprising:

a first station for mounting with the probe and a second station for mounting on the machine;

wherein both the first and second stations hop between a series of different frequency channels;

and wherein the first station transmits a periodic signal at its current frequency and wherein if the

second station receives the signal it will synchronise with the first station, and wherein in the event of a touch trigger event the first station may transmit an additional signal which includes data relating to the time of the touch trigger event and wherein the second station is provided with means for receiving said data station representing the time and producing a probe output signal derived therefrom.

The hopping between frequency channels has the advantage of reducing the chance of unwanted receivers intercepting a transmission, increasing the chance of a transmission getting through to the correct receiver in the presence of unwanted radio traffic.

The use of a periodic signal rather than a continuous signal increases battery life.

If the second station receives the signal transmitted by the first station, it may transmit an acknowledgement signal. If the first station does not receive an acknowledgement signal in response to its signal, it will re-transmit said signal. The ability to re-transmit messages which have not been received enables the system to be capable of operating in a noisy environment.

Preferably the transmission system comprises a half duplex link.

In the second station, the probe output signal is produced after a time delay. This time delay is chosen so that it is long enough to allow retransmissions of the signal, within the time delay.

A master clock is provided at one end of the transmission system and a sliding correlator is provided at the other end to recover the master clock. This provides a reference for the probe trigger time delay. Preferably the acknowledgement signal sent to the probe station is synchronised with the master clock. This removes the need for clock recovery at the first station.

In a preferred embodiment, data bits relating to more important information are provided with greater error protection than other data bits. The data bits relating to more important information may be provided with a higher hamming distance than other data bits.

Preferably, the first station has a standby mode, in which the periodic signals are sent at a slower rate than in its normal mode, and wherein each periodic signal asks if the first station should turn on, and wherein if the first station receives an affirmative response, it turns on. This minimises power consumption and is sufficient to allow the second station to maintain synchronisation with the first station.

Preferably, if the first and second stations are not synchronised, the first and second stations will hop between frequency channels at different rates until second station receives the signal and synchronises with the first station. If the second station detects background noise above a predetermined level on the selected frequency channel, it will change to a different frequency channel.

Preferred embodiments of the present invention will now be described by way of example with reference to the accompanying drawings wherein:

Fig 1 illustrates a touch trigger probe mounted on a machine tool;

Fig 2 is a schematic illustration of the frequency hopping and synchronisation of the first and second stations;

Fig 3 is a schematic illustration showing lost hops and event interruptions;

Fig 4 is a schematic illustration showing a probe trigger and delay counters;

Fig 5 is a schematic illustration showing synchronisation recovery; and

Fig 6 is a schematic illustration of the sliding correlator in the machine station.

Fig 1 illustrates a touch trigger probe 10 mounted on a spindle 12 of a machine tool. The touch trigger probe 10 has a deflectable stylus 14 with a workpiece-contacting tip 16. The signal transmission system comprises two stations, the probe station 18 is connected to the touch trigger probe and is mounted to a moving part of the machine tool. A machine station 20 is mounted on a stationary part 22 of the machine tool structure and is connected to the machine tool controller 24.

Data is transmitted between the probe station 18 and machine station 20 using a frequency-hopping radio communications link, which sends discrete packages of serial binary data.

Both the probe and machine stations hop between

different frequency channels roughly in synchronisation with each other with occasional messages sent between them to synchronise the two stations. The probe station initiates each exchange of messages and receives a reply from the machine station.

The frequency-hopping and synchronisation will now be described in more detail with reference to Fig 2. The machine station is listening for messages most of the time whilst the probe station is in its half-on condition most of the time (e.g. as in slots n+1 to n+3 above). When the probe station is half-on its probe interface and microprocessor will be on and the radio modem will be off. The probe interface and microprocessor each use about 2mW of power whilst the radio modem uses significantly more power, about 120mW when switched on. The radio modem consumes a similar amount of power whether it is receiving or transmitting. The half-on state thus minimises power consumption of the battery powered probe system.

Fig 2 shows the probe station turning on with a small settling time and then transmitting an "I'm OK" message on frequency channel f(n). The probe station then listens for the acknowledgement from the machine station. The machine station which is listening on channel f(n) receives this message, synchronises its clock with the probe station and then sends an acknowledgement back on channel f(n). Upon receiving this acknowledgement the probe station switches back to its half-on condition. The probe station clock therefore acts as the master clock for the system.

The probe station is now silent for a number of time

slots (assuming there are no probe triggers) and the machine station listens on successive frequency channels f(n+1), f(n+2) etc. Fig 2 shows an exaggerated error in clocks between the probe and machine stations. This error is small enough to allow the stations to remain synchronised to the order of 100 silent time slots and is corrected each time the machine station receives a message from the probe station.

For clarity Fig 2 only shows three silent slots and thus three frequency-hops are unused. The periodic timer then prompts the probe station to transmit again on f(n+4) and this cycle then repeats until interrupted by some other event (e.g. a lost transmission, a probe trigger or a probe station turn-off signal).

Transmissions from the probe station may not be received by the machine station due to for example interference. Such a situation will now be described with reference to Fig 3. In Fig 3 settling time is not shown and the effects of synchronisation of clocks and hopping between the probe station and machine station is assumed.

The transmitted radio packet from the probe station includes probe data. For example, the probe may be seated (S) or the probe may have triggered (T). Other information may also be transmitted in the radio packet, for example the condition of the battery, how many transmissions have been attempted for this message and data relating to the time of a touch trigger event.

In time slot n a successful message from the probe

station and reply from the machine station, all on frequency channel f(n) is shown. This confirms that both the probe station and radio link are operating and that the output from the machine station can be trusted.

In time slot n1 the probe station transmits a message, the machine station receives this message and sends an acknowledgement. However the probe station does not receive this reply for example due to interference.

As no acknowledgement is received the probe station will re-transmit the message in the next time slot n1+1. Fig 3 shows the re-transmission of the message from the probe station in time slot n1+1. However, as the machine station receives nothing, it does not send an acknowledgement. The probe station will therefore receive no message and so will re-transmit the message in slot n1+2.

In time slot n1+2 everything works. The machine station receives the probe station message and the probe station receives the machine station acknowledgement. The probe station can therefore return to its half-on condition with its radio modem off.

If however after a predetermined time the machine station does not receive the message from the probe station then either the radio link or the probe station has failed and the machine station will set an error output.

For the first transmission of a message, a normal radio

frequency power level is used, for example 1mW. On subsequent re-transmissions, the radio frequency power level may be increased, thus increasing the chance that the message will get through.

As there is the opportunity of re-transmission at a higher radio frequency power, this enables a slightly lower radio frequency power to be used for normal transmissions. This has the advantage of minimising radio traffic and extending battery life.

In time slot n2 in Fig 3, a probe trigger occurs. An out of sequence transmission must be sent by the probe station to the machine station as soon as possible. The probe station transmits a probe trigger message to the machine station in the next time slot n2+1. As before, the machine station acknowledges the message. A probe trigger message outranks the periodic update and thus when a probe trigger occurs data relating to the probe trigger will be included in the data packet sent in the next transmission.

As illustrated in Fig 4, when a probe trigger occurs a timer in the probe begins counting from zero. The value of this timer t1 is latched at the beginning of the next time slot n+1. This value t1 is transmitted from the probe station to the machine station in a transmission in the next time slot n+1.

The machine station decodes this value t1 from the transmitted message and computes a value tk-t1 where tk is a constant. The machine station loads its own countdown counter with the value tk-t1. At the end of the time slot n+1 the countdown counter is started and

when it reaches zero the probe status output changes to triggered.

The time delay between the probe trigger and the machine station probe output will therefore be t1+ts+tk-t1 = ts+tk, where ts is the time of one time slot. This value ts+tk is constant. The delay between probe trigger and machine station probe output is therefore always the same.

The time constant tk is selected to allow re-transmission of the message if the first transmission (i.e. in time slot n+1) fails. In Fig 4, time slots n+2,n+3 and n+4 are available for re-transmission of the probe trigger message. For a re-transmission a correction is applied to tk-t1 equal to the time taken by the number of unsuccessful transmissions. This correction will be the number of retries done multiplied by the length of a single time slot. The message transmitted by the probe station will include data which indicates which try it is (1st, 2nd, 3rd, etc). Alternatively the probe station can (re-)latch the probe station counter at the beginning of each time slot in which a message will be sent. (This value will be t1 + ts for a message sent in slot n+2, t1 + 2*ts for a message sent in slot n+3 and so on.) Thus whichever time slot the message is successfully transmitted in, the total time delay will be constant (=ts+tk) between the probe trigger and the machine station probe status output.

For the probe station and machine station to communicate they must both be set to the same frequency channel at the same time. To achieve this the probe

station frequency channel controller and the machine station frequency channel controller must be synchronised. This is achieved by a synchronisation recovery/find and collect process described below with reference to Fig 5.

The probe station is shown hopping between frequency channels at normal speed (e.g. one hop per millisecond) and the machine station is shown hopping at a much slower speed (e.g. one hop per 50 milliseconds). The probe station transmits in every time slot (n, n+1, n+2 etc) and then listens for a reply before hopping to the next time slot. The probe station transmission contains the ID number of the probe and includes a request for synchronisation and acknowledgement of the message. The machine station listens for many probe station time slots and occasionally changes to a different frequency channel. In time slots n, n+1 and n+2 in Fig 5 the probe station is shown transmitting on successive different frequency channels whilst the machine station listens. However whilst the machine station is on a different frequency channel to the probe station it receives nothing.

In time slot n1-4 the machine station is shown hopping to a new frequency. Meanwhile the probe station continues hopping frequency channels and transmitting. In slot n1 the probe station and the machine station are on the same frequency channel and the machine station hears the message from the probe station and synchronises its time slot clock to the probe station. The machine station is now synchronised with the probe station and a periodic handshake to maintain synchronisation can now occur. The machine station

acknowledges the message from the probe station in the time slot n1.

Usually the acknowledge message from the machine station will be received by the probe station. However Fig 5 illustrates what happens if the probe station fails to hear the acknowledgement. In time slot n1 the machine station transmits an acknowledgement but although the probe station is listening it does not receive the acknowledgement. The probe station hops to the next time slot n1+1 and again transmits its message. As the machine station is synchronised it will be listening on the correct frequency channel in time slot n1+1 and will thus hear the message from the probe station. The machine station will synchronise its clock again and will acknowledge the message again. The probe station message in slot n1+1 is effectively a re-transmission as shown in Fig 3.

During the process of synchronisation recovery, if the machine station hears significant noise on a certain frequency channel, it will immediately hop to another frequency channel rather than wait on the frequency channel where background noise may swamp any transmission from the probe station.

It is desirable to be able to turn on the probe station via a radio message from the machine station. Whilst waiting for this radio turn-on the probe station is in its radio standby mode in which it consumes substantially less battery power than when it is in its operating mode.

The probe station radio standby mode is similar to the

periodic update, although the time slots may be wider and the cycle time longer, i.e. slow hopping between frequency channels.

Most of the time the data exchange will consist of the probe station transmitting its ID number and asking it if should be turned on, whilst the machine station replies that it is not needed. As with the operating mode the machine station is synchronised to the probe station during this exchange. If the probe station does not receive an acknowledgement from the machine station it will re-try to transmit the message in subsequent time slots in different frequency channels.

If it is required to turn-on the probe station, the machine station will reply "turn-on" and change to operating mode. The probe station will then switch to the operating mode. In the operating mode the machine station will maintain synchronisation with the probe station as described above.

Turn-off will require an exchange of messages as the turn-off request may come from the machine station or alternatively from the probe station (for example a time out). Following turn-off both probe and machine stations will return the synchronised slow hopping described above.

As discussed earlier, the radio signals between the probe and machine stations consist of message packets of serial binary data. Each message contains a header which includes probe station identity data, or address, needed to enable the machine station receiver to recognise whether the message is intended for that

receiver and to synchronise a clock in the machine station to the probe station clock.

The machine station uses a correlator to recognise the incoming message header.

Fig 6 illustrates the sliding correlator used in the machine station. A radio frequency receiver and de-modulator 26 receive radio signals transmitted from the probe station and output a serial stream of received data into a large shift register 28.

On each pulse of an oversampling clock 30, the incoming serial data stream is sampled and its value (1 or 0) is loaded into the shift register 28. Simultaneously the contents of the register are shifted right 1 bit, the last bit being shifted 'off the end' and lost.

A target word is held in a separate target register 32. The entire shift register contents are continuously, in parallel, bit to bit compared with the target register contents by an array of exclusive-or (EOR) gates 34. One EOR gate is used per bit of the shift register and the outputs of the EOR gates are added at an Adder 36 to determine the number of bit-matches detected.

The number of bit matches detected is then fed to a comparator 38, where it is compared with the required number of matches threshold 46, which is typically greater than 95%, to determine the correlation detected binary output 42.

The target word is programmable, thus the correlator

can be set to detect different desired bit sequences. In particular, the target word is set to the expected header sequence which will be sent from the transmitter (i.e. the acquired partner probe station).

In a typical system the header could be a 32 bit word with a data rate of 1 bit / microsecond. The oversampling clock might run at 10 times the data rate, i.e. 10MHz and the threshold could be 95% match. Thus the shift register would contain 10 x 32 = 320 flip-flops, and the EOR gate array would contain 320 EOR gates. The outputs of the 320 EOR gates would be fed to the adder, which would output a number between 0 and 320 to the comparator. To achieve a 95% or better match, the threshold would be set at 320 x 0.95 = 304 bits. Thus if 304 or more bits in the shift register matched their targets from the target word, the correlation detected output will be True, otherwise it will be False. This test is done and the correlation detected output updated on every pulse of the oversampling clock, i.e. every 100 nanoseconds.

The advantage of this system is that clock recovery is only required at one end of the half duplex link. The master clock is provided at the probe station. At the machine station, the sliding correlator is used to recover the clock data from the messages transmitted from the probe station. The sliding correlator provides a reference for the probe trigger time delay and allows acknowledgement messages to be sent already synchronised, thus removing the need for clock recovery at the master end of the link (i.e. at the probe station).

There are two main types of possible correlator errors. The correlator may fail to identify a transmitted message, described above or a correlator may report a match when no message has been transmitted.

If the machine station falsely believes that it has received a message from the probe station, this will result in loss of the synchronisation of the machine station clock, failure of the radio link and an error message being produced. The probe station only listens for a machine station acknowledgement immediately after it has sent a message and the machine station acknowledgement is thus expected within a very narrow timeslot.

When in the operating mode, a failure will occur when noise imitates a machine station acknowledgement and thus prevents the probe station from re-transmitting the message. However the probe station is only vulnerable to this error when it is waiting for an acknowledgement which doesn't come.

The transmitted message contains several different items of information, such as probe station address, probe status (i.e. seated or triggered), timestamp (i.e. time of probe trigger) and battery status. Some of these items have high importance, such as the probe station address and the probe status. The timestamp has high importance if the probe status is 'triggered' but is otherwise not important. The battery status has low importance.

In order to optimise error protection of the transmission, the most important data bits of the

message are encoded with a large hamming distance. This allows small numbers of bit errors to be corrected and larger numbers of bit errors to be rejected. A higher hamming distance has the advantage of allowing some error correction but has the disadvantage that it increases transmission time. Less important data is provided with a lower degree of error protection, for example multiple bit error detection using a cyclic redundancy check.

For example, the probe station address and probe status data may be encoded with a hamming distance of 6, which could allow 1 bit error correction and 4 bit error detection. The timestamp and battery status may be encoded with a lower hamming distance of 4 which could provide 3 bit error detection.

The information required during the periodic transmissions (probe station address and probe status) thus has higher error protection than other information in the message. There are several empty timeslots between each periodic transmission which are available for re-transmissions if the transmission fails. However, if all these timeslots are used up by unsuccessful re-transmissions, an error signal will be produced and the whole system will stop. It is therefore advantageous to have a high reliability periodic transmission, leaving the empty timeslots as a safety buffer.

In the event that the probe status is 'triggered', the timestamp data becomes important. This data has a lower hamming distance and will be retransmitted if an error is detected.

There may be, for example, about 50 periodic transmissions per second and about 1 trigger per second. It is therefore more important to avoid re-transmissions on the periodic transmission than the trigger signal.

The system of using longer hamming distance codes for the more important data has the advantage that it reduces the number of retransmissions required for the periodic transmissions. As the lower priority data is given lower hamming distance codes, the transmission time is reduced. The radio traffic and battery life are thus also reduced.

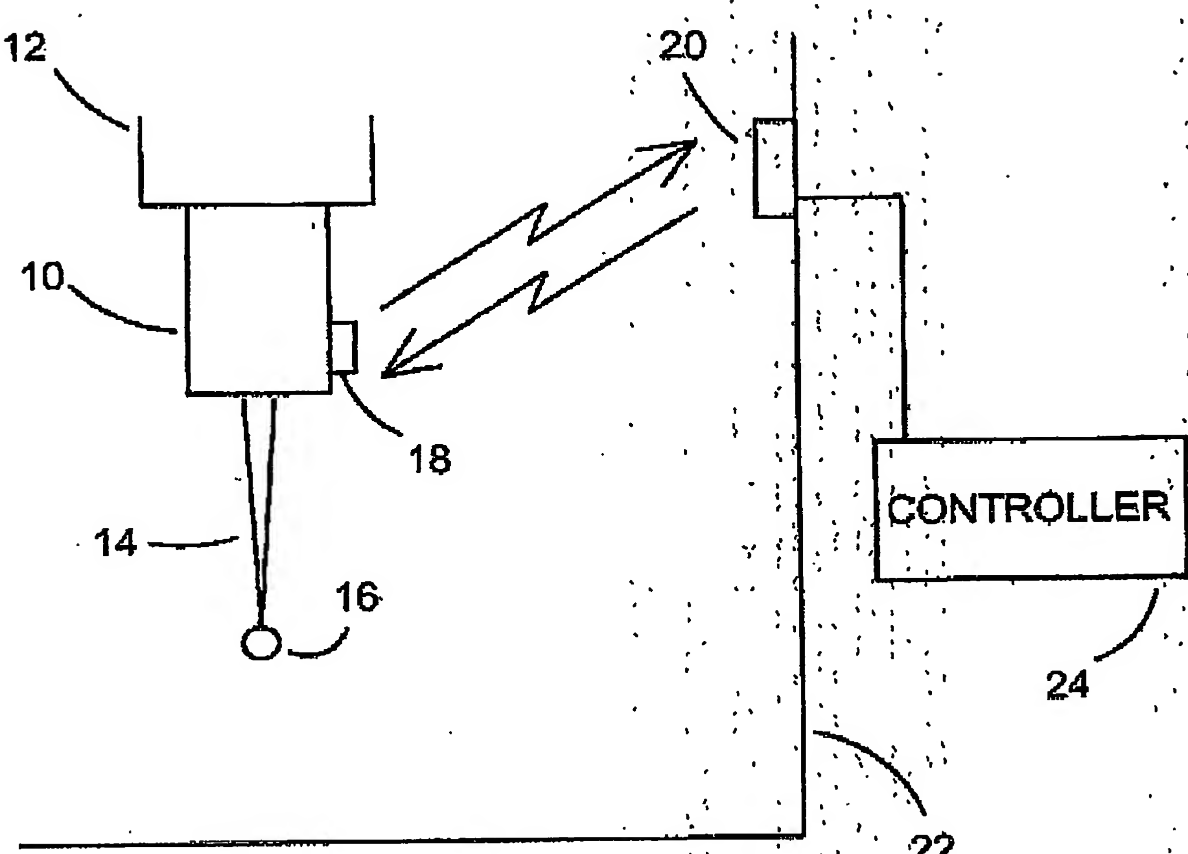
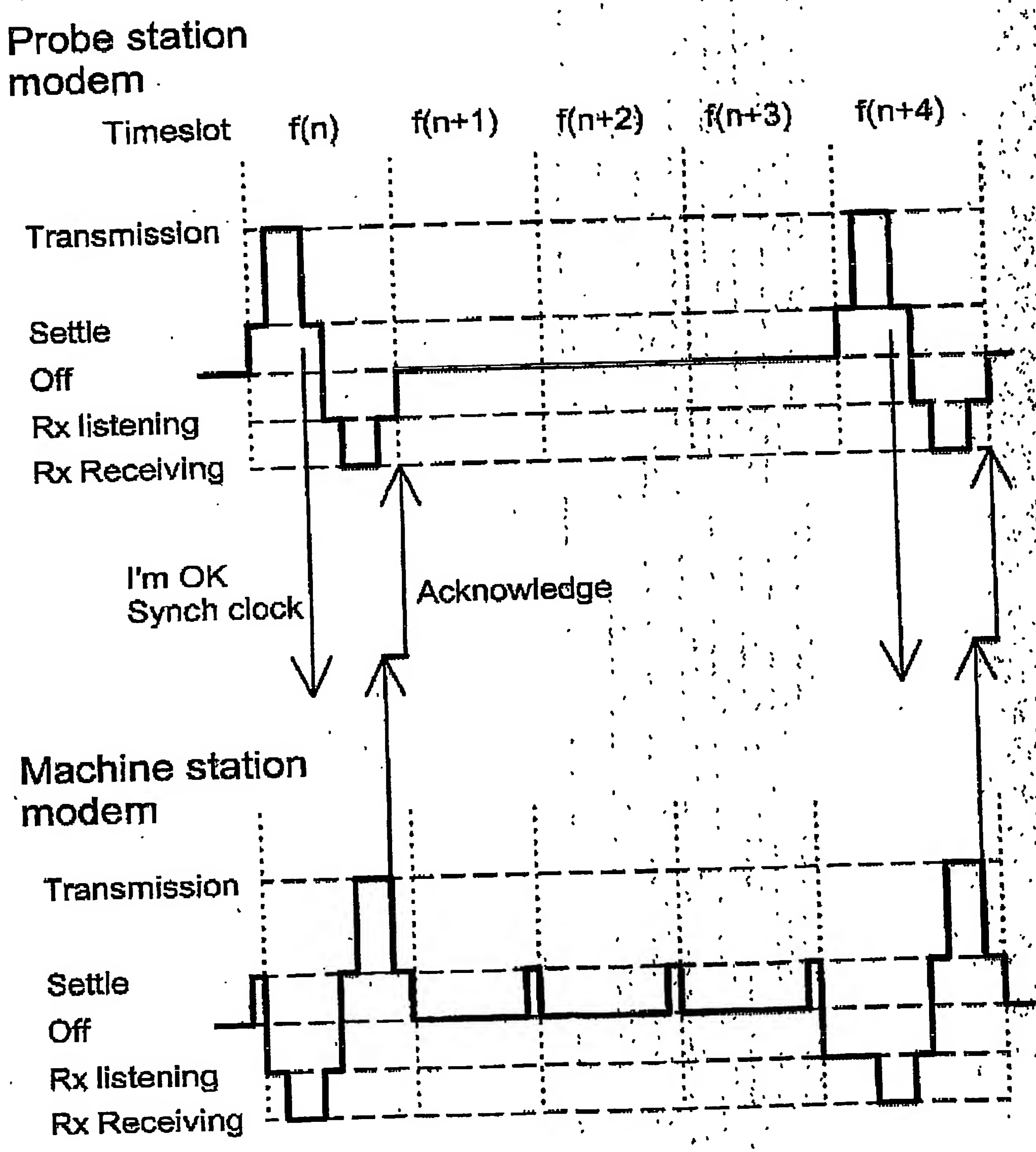
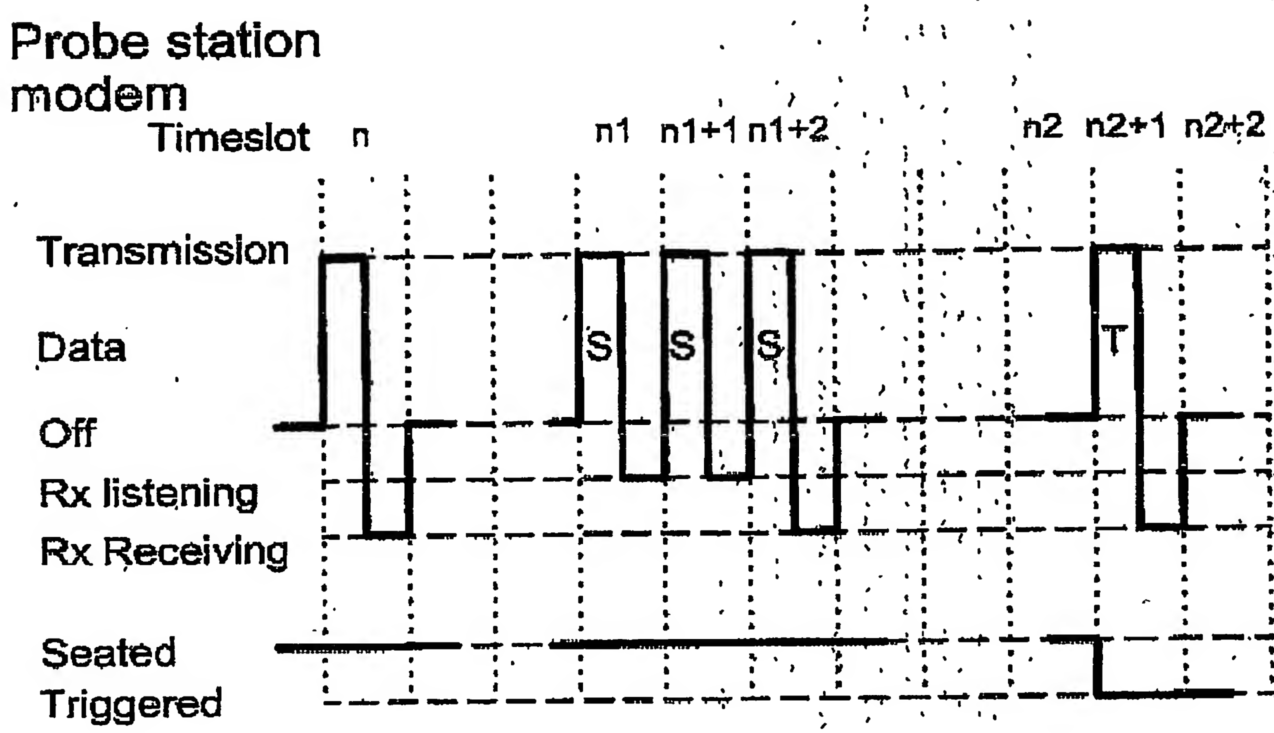



Fig 1



Probe station modem
Timeslot
f(n)
f(n+1)
f(n+2)
f(n+3)
f(n+4)
Transmission
Settle
Off
Rx listening
Rx Receiving
I'm OK
Synch clock
Acknowledge
Machine station modem
Transmission
Settle
Off
Rx listening
Rx Receiving


Fig 2


Probe station modem
Timeslot
n
n1
n1+1
n1+2
n2
n2+1
n2+2
Transmission
Data
S
S
S
T
Off
Rx listening
Rx Receiving
Seated
Triggered

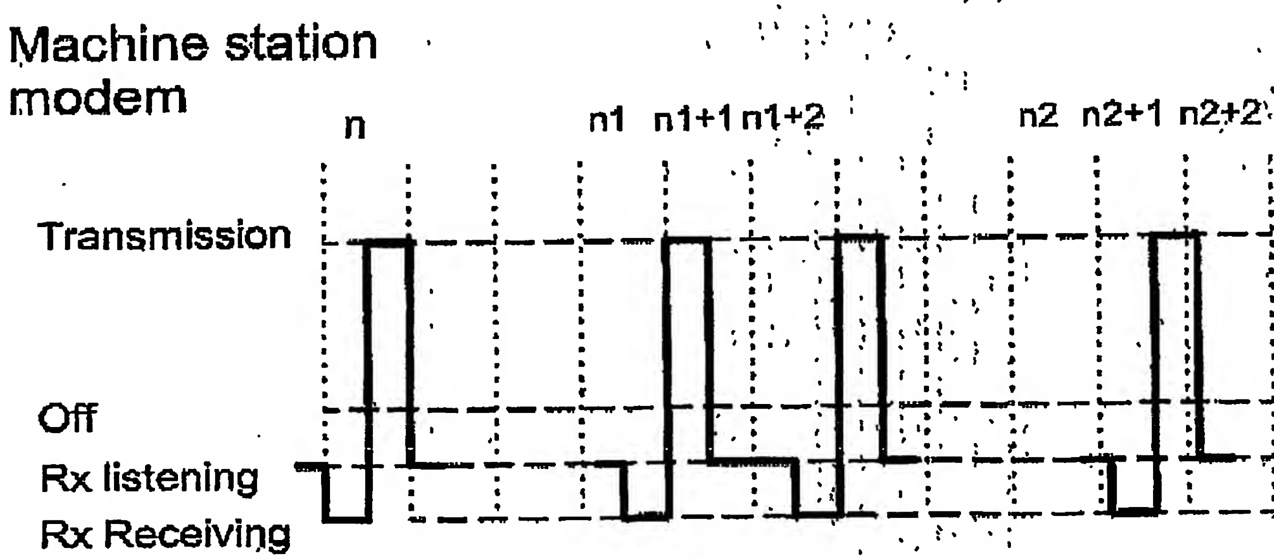
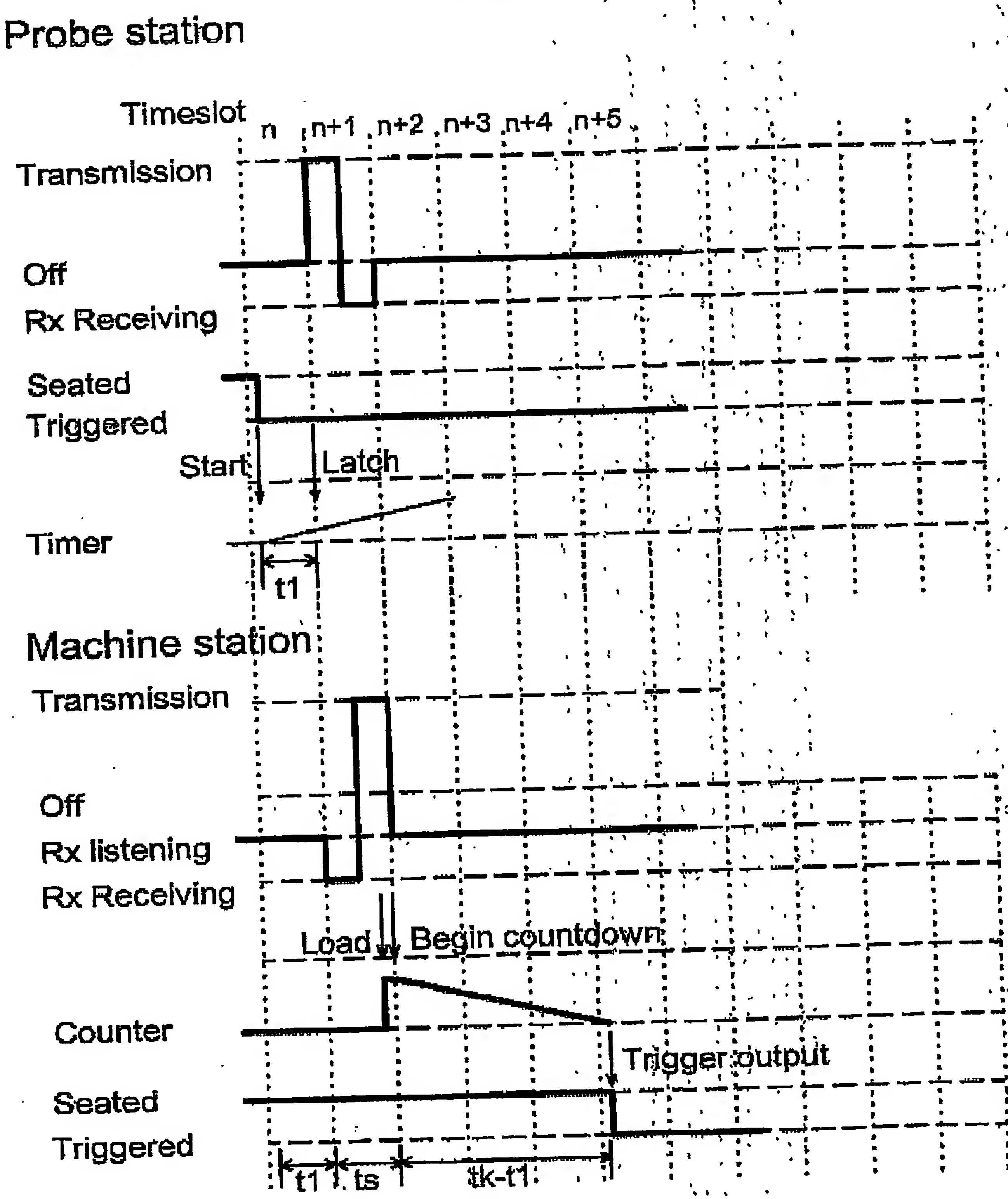
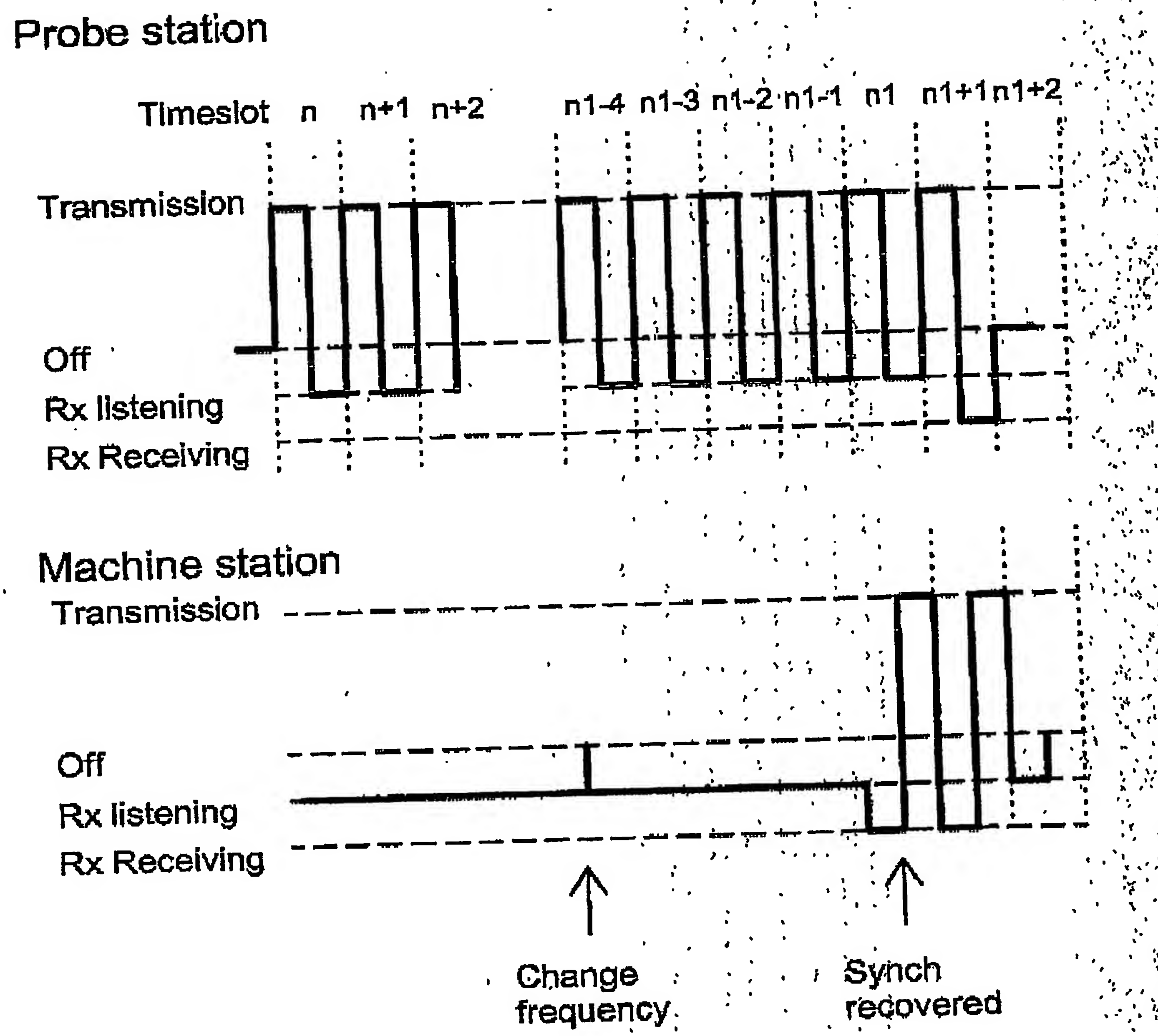

Machine station modem
n
n1
n1+1
n1+2
n2
n2+1
n2+2
Transmission
Off
Rx listening
Rx Receiving

Fig 3



Probe station
Timeslot
n
n+1
n+2
n+3
n+4
n+5
Transmission
Off
Rx Receiving
Seated
Triggered
Start
Latch
Timer
t1
Machine station
Transmission
Off
Rx listening
Rx Receiving
Load
Begin countdown
Counter
Trigger output
Seated
Triggered
t1
ts
tk-t1


Fig 4



Probe station
Timeslot n n+1 n+2 n1-4 n1-3 n1-2 n1-1 n1 n1+1 n1+2
Transmission
Off
Rx listening
Rx Receiving
Machine station
Transmission
Off
Rx listening
Rx Receiving
Change frequency
Synch recovered


Fig 5

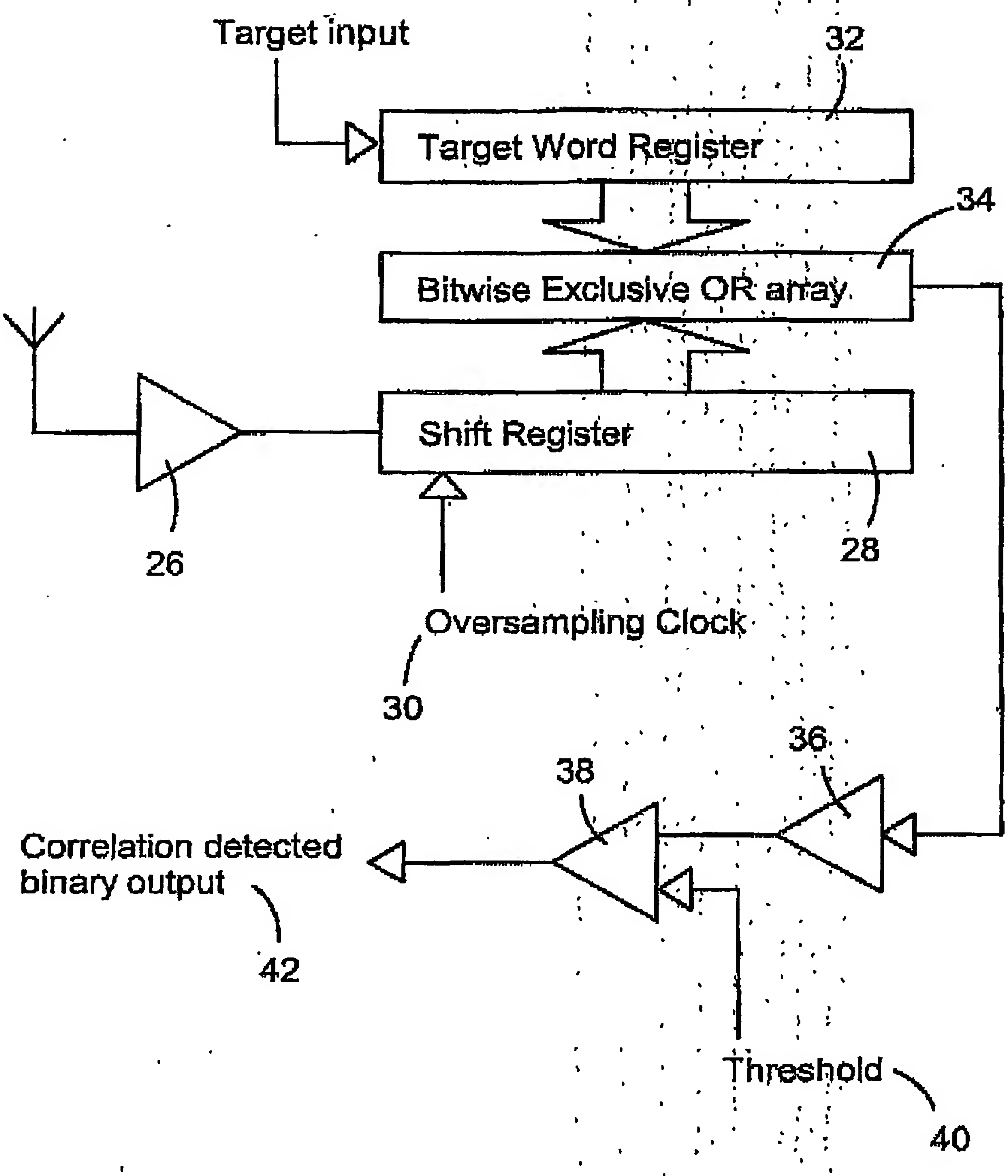

Target input
32
Target Word Register
34
Bitwise Exclusive OR array
Shift Register
26
28
Oversampling Clock
30
36
38
Correlation detected binary output
42
Threshold
40

Fig 6

PCT Application
GB0305516